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DOT HS-803 249

RESEARCH SAFETY VEHICLE - PHASE II

VOLUME I EXECUTIVE SUMMARY

D. Friedman
D. Struble

Contract No. DOT-HS-5-01215
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Minicars, Inc.
35 La Patera Lane
Goleta, CA 93017

Dept. of Transportation
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NOVEMBER 1977
FINAL REPORT

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Prepared For:

U.S. DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration
Washington, D.C. 20590

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Volume I of III Volumes

16. Abstract

Volume I summarizes the results of the Minicars Research Safety Vehicle Phase II program, as detailed in Volumes II and III.

Phase I identified trends leading to the desired national social goals of the mid-1980's in vehicle crashworthiness, crash avoidance, damageability, pedestrian safety, fuel economy, emissions and cost, and characterized an RSV to satisfy them.

In Phase II an RSV prototype was designed, developed and tested to demonstrate the feasibility of meeting these goals simultaneously. Although further refinement is necessary to assure operational validity, in all categories the results meet or exceed the most advanced performance specified by "The Presidential Task Force on Motor Vehicle Goals beyond 1980."

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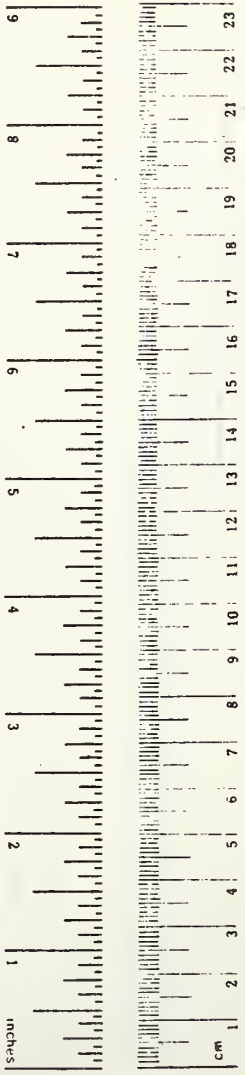
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

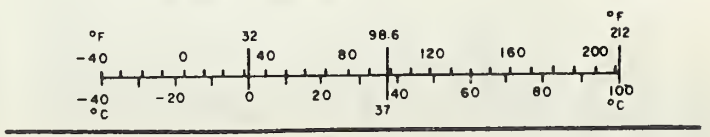
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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6.0 STANFORD RESEARCH INSTITUTE
7.0 SYSTEMS TECHNOLOGY, INC.
8.0 UNIVERSITY OF UTAH

MINICARS, INC. EAGLE II

1.0 INTRODUCTION

The primary motivation for the Phase II Research Safety Vehicle effort was to develop a technological data base to support formulation of U.S. Federal Motor Vehicle Safety Standards applicable to the mid-1980's time period. The objective was to develop a vehicle and experimentally demonstrate its performance in accordance with specifications derived from social requirements in Phase I.

Results support the findings of "The Presidental Task Force on Motor Vehicle Goals Beyond 1980" (MVG Study) and demonstrate that marketable automobiles can be manufactured to meet and exceed the federally legislated national social goals in safety, emissions, energy, and economy by 1985.

2.0 RULEMAKING CONTRIBUTIONS

The RSV program provides data relating to almost all Federal Motor Vehicle Safety Standards and Advanced Notices of Proposed Rulemaking as specified in Appendix A of the Safety Panel Report of the MVG study, including those of Sections A-C (Crashworthiness, Crash Avoidance, and Damageability, respectively). Most importantly from a rulemaking point of view, the RSV program has shown that safety goals can now be formulated in terms of reduced societal losses, and performance standards can be related in a rational way to societal goals. More specific observations are described in the following pages.

- The societal cost accounting methodology developed in Phase I and extended in Phase II allows performance standards to be established from the distribution of existing societal costs (below) and in accordance with the National goals for reducing automobile accident casualties and property damage.

Distribution of Societal Costs

Accident Mode	Percent Total Societal Cost	50th Percentile Closing Velocity (mph)	75th Percentile Closing Velocity (mph)
Vehicle-to-Vehicle			
Frontal	47.5	67	90
Side	25.4	36	48
Rear	5.8	26	38
Fixed Object			
Frontal	9.2	34	46
Side	4.4	39	49
Rollover	8.0	43	57

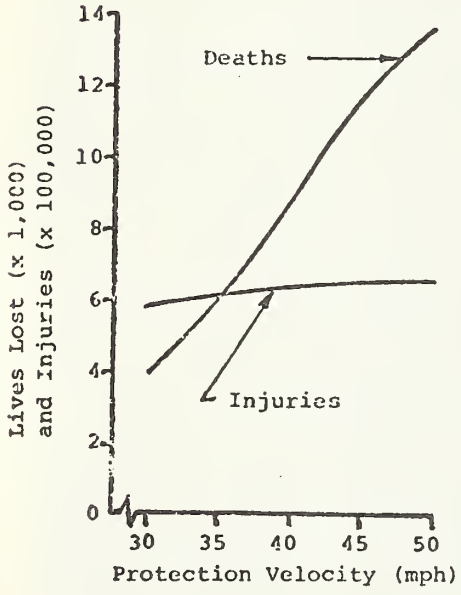
- Specifying safety performance on the basis of occupant injury in real-world accident modes has been shown to be practical. For instance, in frontal accidents under 30 mph, 4,000 lives can potentially be saved (26% of total) and 587,000 injuries (90% of total) can be averted. As seen in the plot below, the number of lives which could be saved increases dramatically as the protection velocity is raised.

- Rulemaking priorities can now be assigned on the basis of maximum benefits at minimum cost. For instance, during Phase II:

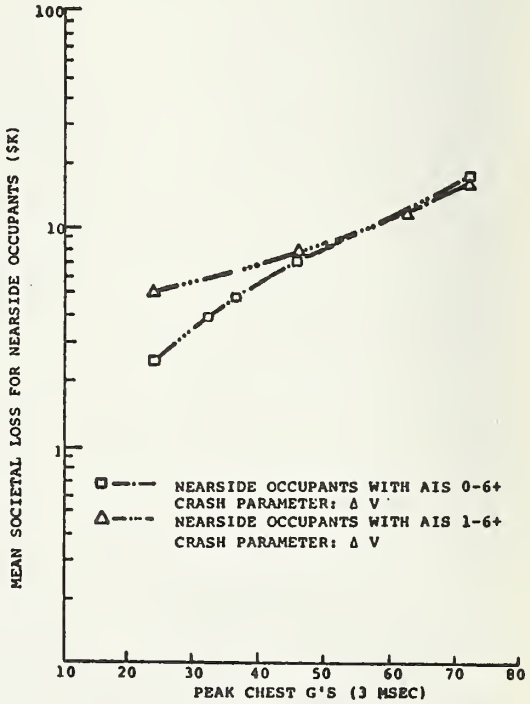
1. Dummy injury measures were correlated with societal loss in side impact accidents as shown below. These correlations are similar to those previously defined for frontal accidents.

2. Tests showed that the strength characteristics of conventional small cars are substantially weaker than those of full-sized cars and the fronts of almost all cars.

3. The conclusion was that compliance with MVSS 214 is not adequately improving occupant protection in car-to-car side impacts. For improved safety at minimum cost, small cars will require increased side structural stiffness and padding thickness.



Frontal Crash Statistics



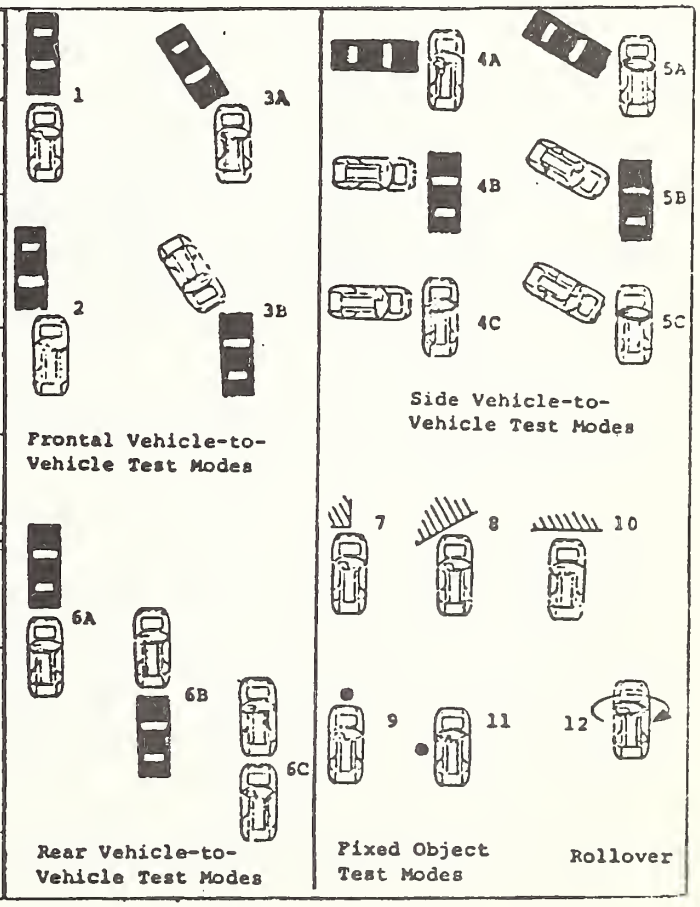
Injury Measure to Societal Loss Relationships for Nearside Occupants

- Compliance tests for frontal and front-to-side performance and compatibility can be derived. Static tests, computer simulations, dynamically investigated mass and geometry effects can be combined with dummy injury measures (correlated with human injury) to determine benefit. By investigating cost for alternate implementations, benefit/cost and cost effectiveness potential can be determined.

  1. Although the procedure involves extensive testing (see below) with representative vehicles of each weight class in real-world accident modes, the testing need only be performed once to derive and adequately relate simplified repeatable compliance tests to real-world compatibility and to the potential societal benefit.

  2. The RSV results indicate that the compatibility of the front of any vehicle with the weaker side strength of small vehicles at societal-cost-significant velocities cannot be achieved using softer front structures alone.

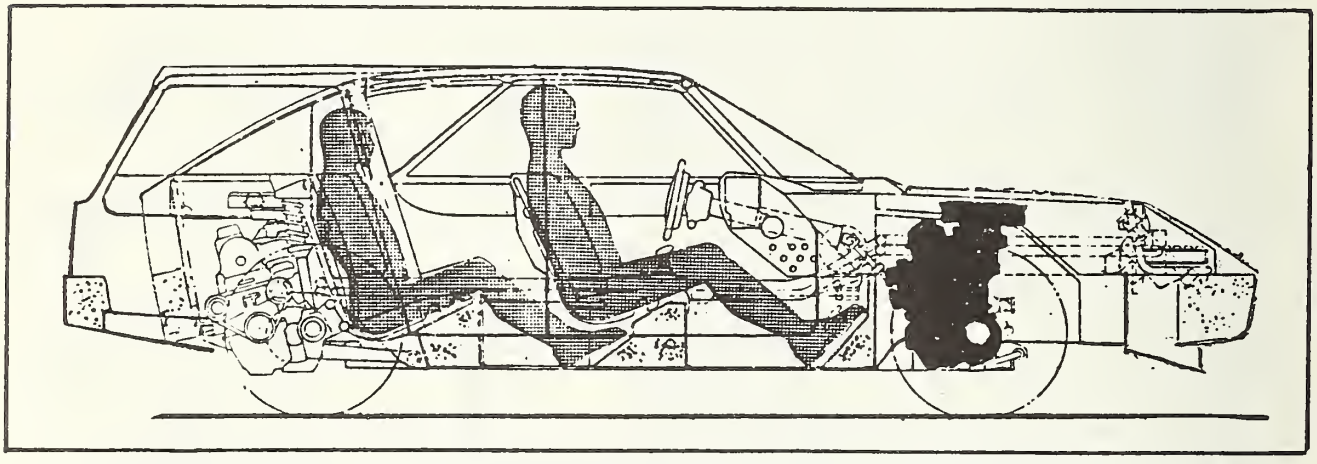
Test	No. of RSVs Req'd	Number of Other Vehicles Required			
	RSV	Other Vehicles			Braking Involved
	R	3000#	2000#	4000#	3000#
1	6	3	1	1	1
2	6	3	1	1	1
3A	6	3	1	1	1
3B	6	3	1	1	1
4A	5	2	1	1	1
4B	5	2	1	1	1
4C	4				
5A	5	2	1	1	1
5B	5	2	1	1	1
5C	4				
6A	5	2	1	1	1
6B	5	2	1	1	1
6C	4				
7	2				
8	2				
9	2				
10	2+				
11	2				
12	3				
Total	79	24	10	10	10



3. Based on the results of Phase IV type tests on integrated test vehicles, cost and weight increments required for varying levels of frontal, side, and rear impact performance and compatibility can be estimated for each weight class and among weight classes.

- Compromises required to integrate subsystems individually developed into one vehicle substantially affect performance, weight, and cost. However, weight and cost increments for alternate safety performance levels and vehicle configurations may be assessed and easily demonstrated by extrapolating the RSV-developed design to substitute:

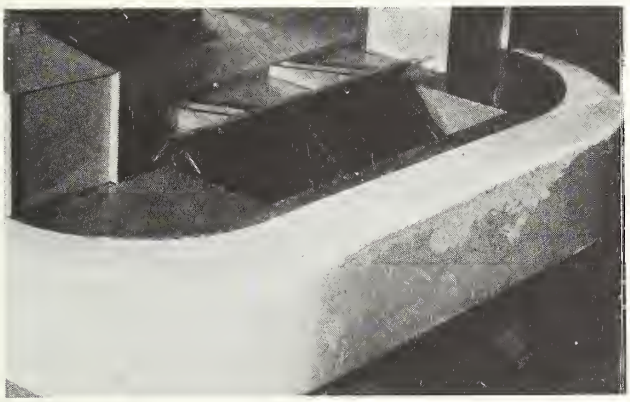
  Front Wheel Drive/Engine
  Passive 3-Point Force-Limited Restraints
  Alternate Engine/Transmissions
  Conventional Doors and Windows
  Configurations for Various Vehicle Sizes



Front Engined RSV Sports Wagon with Four Conventional Doors

- Very significant progress has been made in developing an appropriate and effective radar/microprocessor/anti-skid braking/display electronics system for crash mitigation and avoidance. Although the system must be extensively refined and tested, sufficient information is already available to indicate that using sophisticated automotive electronics is cost effective. The effectiveness of, and compatibility among, driver aid subsystems, controls, restraints, vision, and tires is also being validated by the RSV.

- Damageability standards are supported by the extremely lightweight no-damage bumpers developed. Although front-to-rear bumper height compatibility was considered in the design, testing and refinement are required.



- Repair costs and pedestrian injury in impacts to 20 mph are greatly reduced as demonstrated by tests conducted on the flexible polyurethane "body glove" (vehicle skin) and replaceable nose section. Such performance suggests and would support rulemaking in these areas.

- In the safety-related area, the Minicars RSV Phase II program has demonstrated that anticipated future motor vehicle safety rulemaking and standards for fuel economy and emissions are compatible and can be met and exceeded with a producible, marketable, and relatively economical product.

- Minicars recommends that the development of a data base for rulemaking support be an objective of future procurements. Priority would then be assigned to analyzing the cost effectiveness and benefit/cost relationships for all subsystems to all vehicle classes, to support RSV developed conclusions.

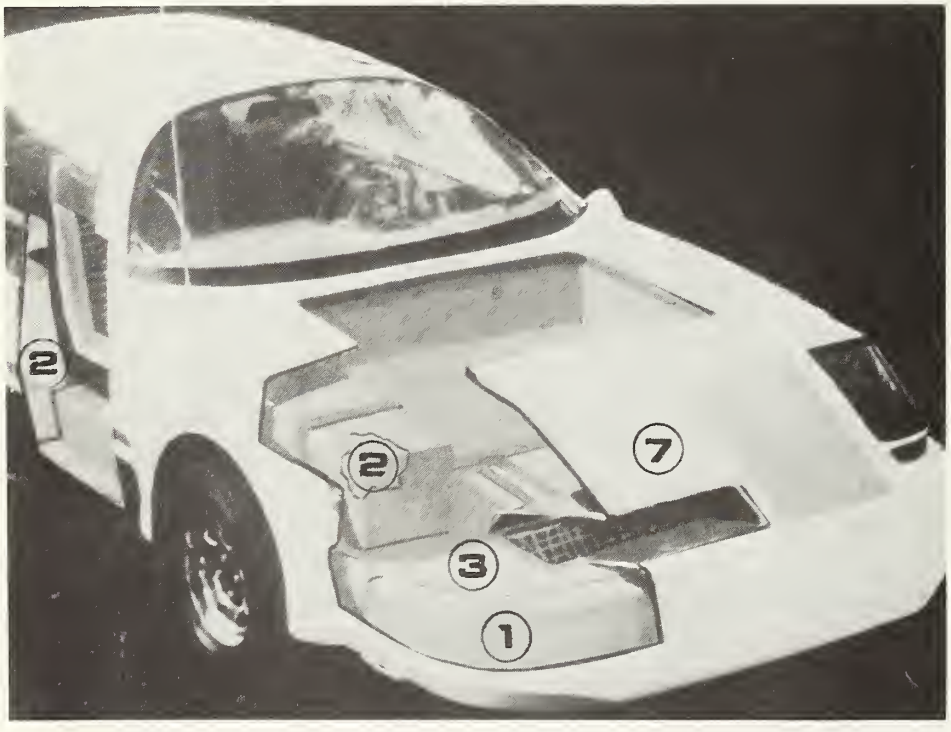
- An expansion of integrated test vehicle programs incorporating subsystem contract developments into new or modified vehicles is necessary to support the rulemaking process because of:

  1. Specificity limitations that must exist in subsystem contracts;

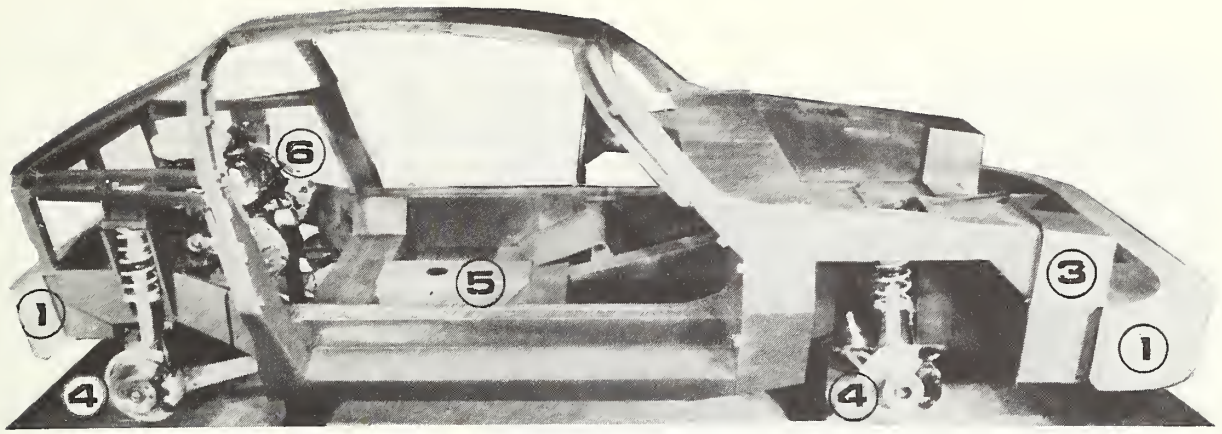
  2. The serendipity, synergistics, producibility, and goal-coordination potential of a systems program; and

  3. The possibility to explore and integrate new, upper-limit performance subsystems.

The objective of the RSV program to develop a vehicle and experimentally demonstrate its performance has been satisfied in Phase II to the extend described in the following pages.



RSV Front Structure Configuration



RSV Structural Architecture

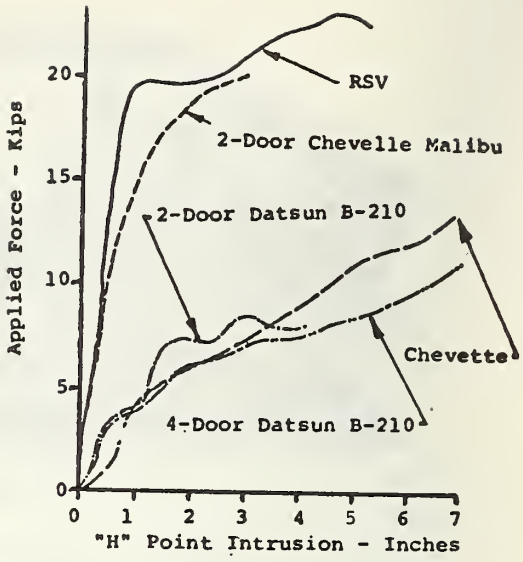
3.0 VEHICLE DEVELOPMENT

3.1 Structure/Running Gear

The vehicle structure is fabricated of sheet metal typical of unitized body production, configured to include closed volumes, foam-filled for improved crash energy management. The gullwing doors rest against strong shut faces. High strength rollbars and roof struts and rails form the upper structure. Some design details, keyed to the adjacent figures, include:

1. Semirigid polyurethane bumpers* which are damage-free in 10-mph frontal and 5-mph rear collisions.
2. Rigid foam, acting as a lightweight energy absorber in collisions, which is encapsulated by sheet metal. This technique also reduces potential foam flammability and toxicity.
3. The bolt-on replaceable nose section supporting the bumper which limits aggressivity and can sustain all the damage in a 20-mph impact.
4. Fiat X1/9 four-wheel independent suspension, disc brakes and calipers which are modified to couple with the ITT-TEVES anti-skid system.
5. The fuel storage cell which is well protected by the structural cross members.
6. The Honda CVCC Accord engine and the five-speed transmission which have been adapted with Honda's guidance.
7. The damage-resistant, soft, resilient plastic "body glove" which stylishly covers the structure also provides pedestrian impact protection.

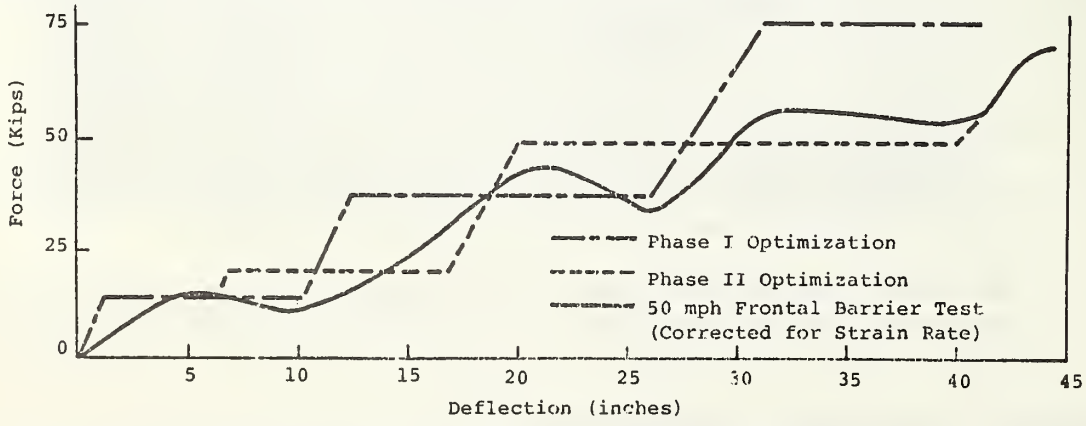
*Bumpers, rigid foam, and body glove were specially formulated by Monsanto Research Corporation.



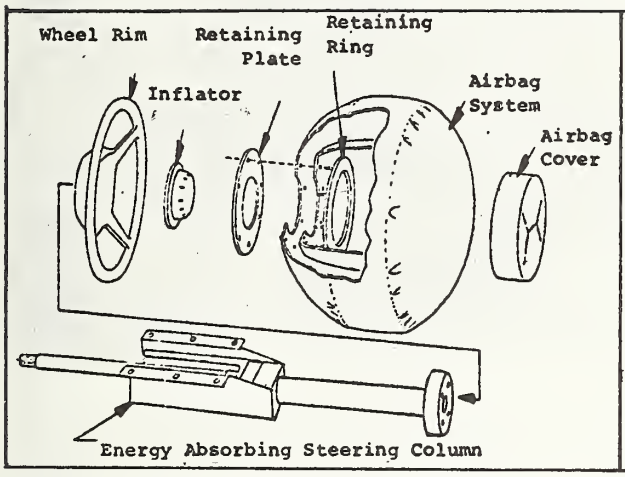
3.2 Compatibility

Structural resistance to crush was measured at the Minicars static test facility. The above photo shows a hardened RSV nose being pushed into the side of a 1975 Chevelle. Load cells measure the force level as a function of crush distance. To establish the side impact data bank, Chevettes, Pintos, Datsuns, and the RSV were similarly crushed. The RSV and Chevelle results show these vehicles to be twice as strong as the other cars tested. Computer simulation of available front-end crush data enabled Minicars to improve RSV front-end compatibility with the weak sides of small cars.

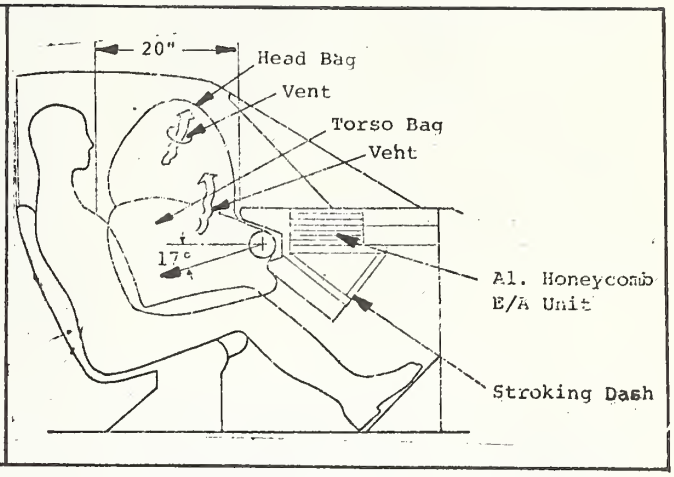
The crash pulse for the RSV as originally proposed for 50-mph frontal barrier impacts is presented below. Since this initial design, the crash pulse of the RSV has been modified to maximize the initial vehicle crush to improve compatibility with conventional car side structures. Also shown below is the final RSV test pulse shape. It is clear that the new intermediate plateau is only slightly above the bumper crush plateau.



RSV Frontal Crush Characteristics



Driver Airbag Assembly

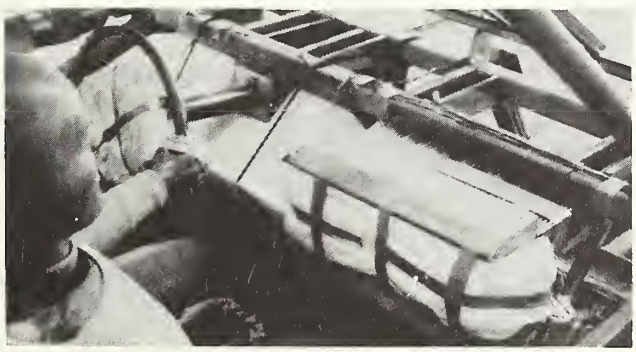


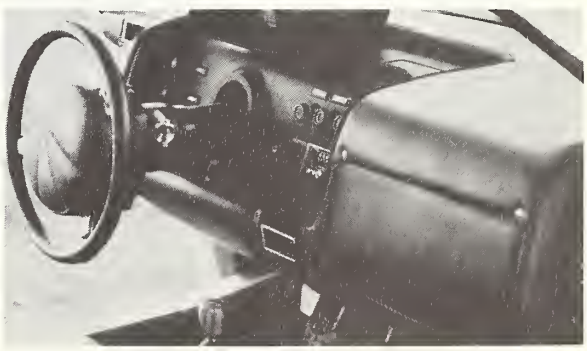
Right Front Passenger Restraint

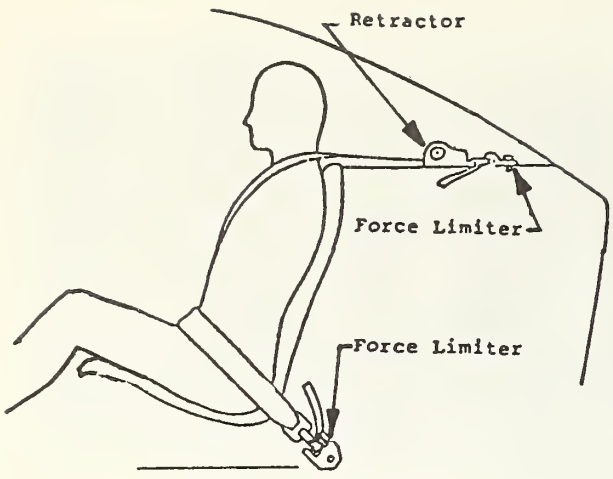
3.3 Restraint Systems

The Minicars RSV is equipped with the most advanced occupant protection systems available. Front seat occupants are protected in 50-mph frontal and 45-mph frontal oblique impact collisions by dual-chambered air cushion restraints. These restraints deploy in 25 milliseconds to completely protect occupants without aid from lap belts or other types of active restraint systems.

Restraint systems for driver and front passenger protection are conceptually and functionally similar, though differing in appearance. Each restraint is comprised of an inflator and an air cushion containing two chambers--one for the head and one for the torso. This design feature provides high speed protection by restraining the torso quickly and firmly and cushioning the head relatively more softly and more slowly. Driver and passenger lower body trajectories are controlled by foam knee pads located under the driver and front passenger dash.





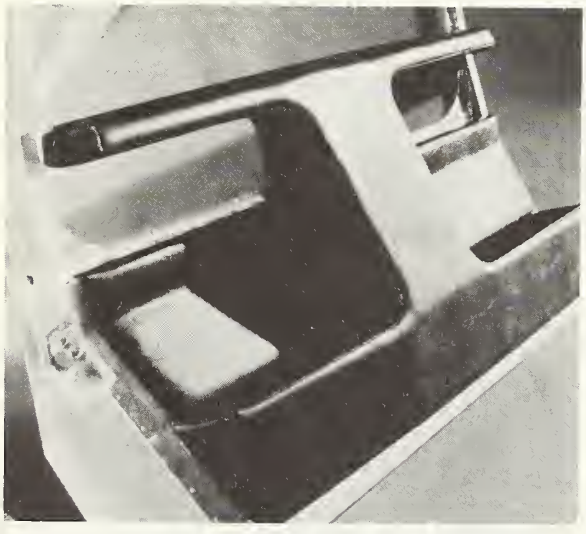


Rear Seat Restraint Configuration

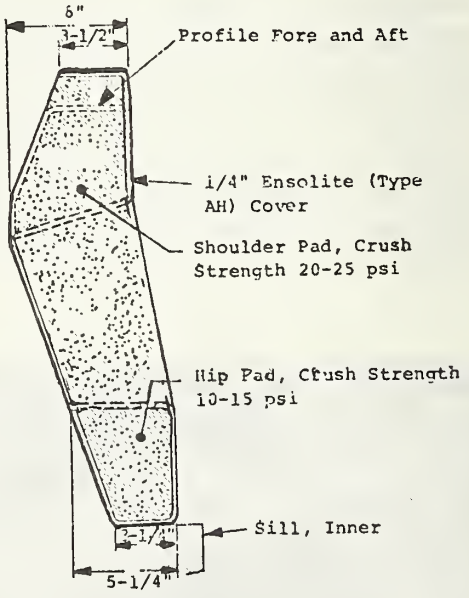
Gullwing Door Configuration

The RSV rear seat restraint, similar in configuration to the conventional 3-point harness, uses force limiters at each anchor location and low-stretch polyester webbing to protect occupants in impacts over 40 miles per hour.

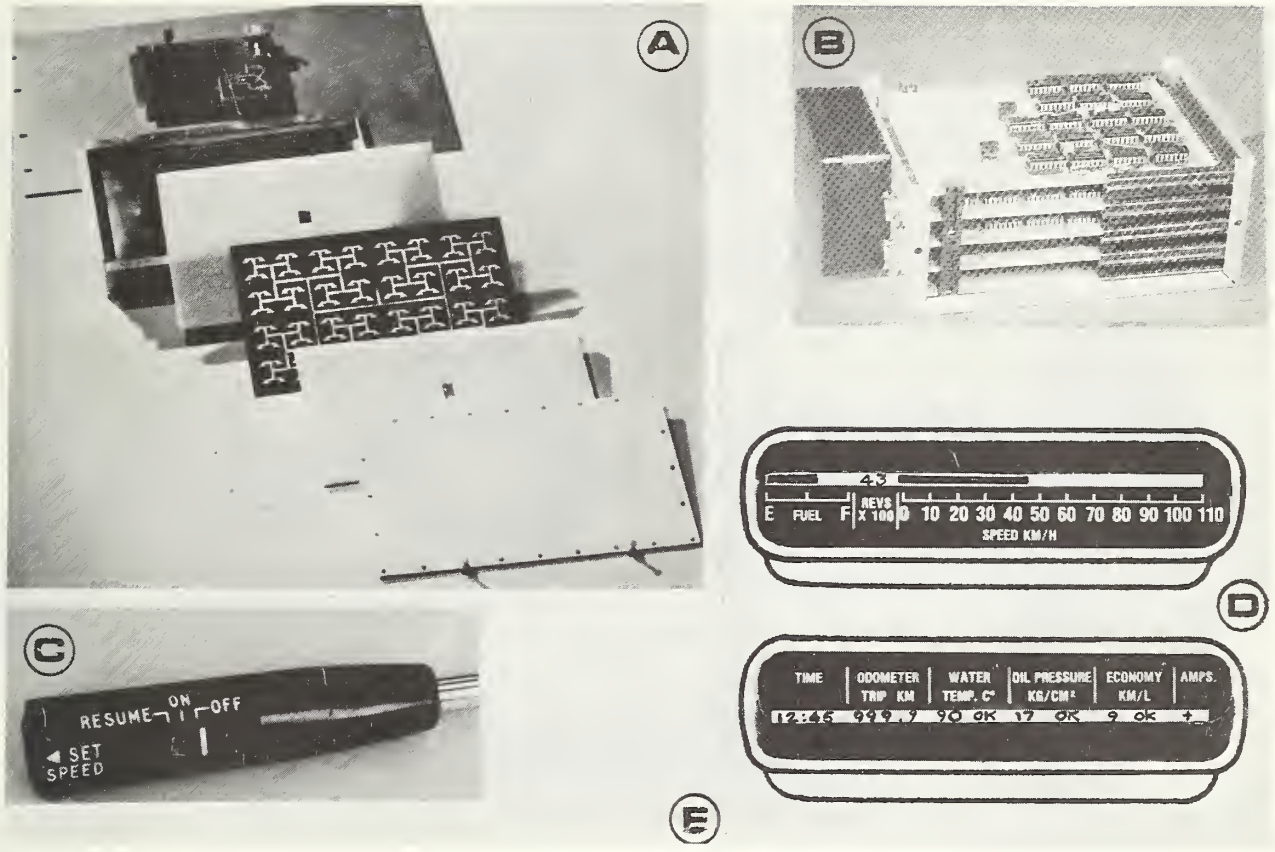
RSV side impact and rollover protection is afforded by the specially constructed gullwing door and the well designed vehicle interior. The exterior structure of the RSV door works in conjunction with the interior padding to attenuate occupant lateral impacts. Head impact energy is absorbed and ejection is prevented by using fixed side glazing. Crashworthy door latches and the fixed side glazing prevent occupant ejection during lateral and rollover collisions.



Interior Door Padding



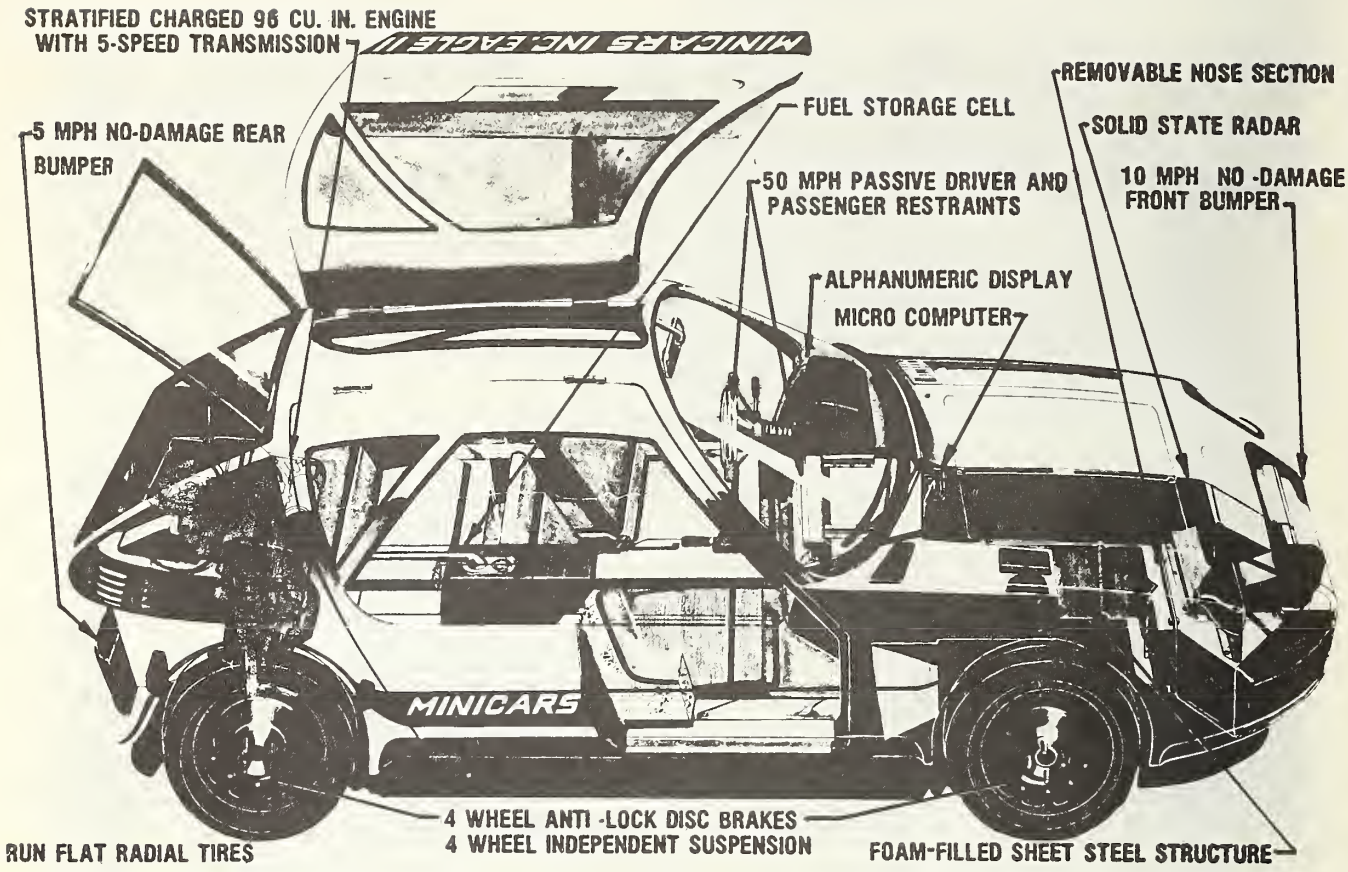
Door Padding Center Section



3.4 Electronics

Information from the solid-state radar (A) is interpreted by a microcomputer (B). This interface provides the most advanced and innovative driver aid and warning system available. A "smart" cruise control feature (C) alerts the driver and slows the vehicle when the car ahead is being approached too quickly. The system will also provide an audible signal to warn of possible dangerous situations. It will automatically actuate the high performance braking system only if a serious collision is unavoidable.

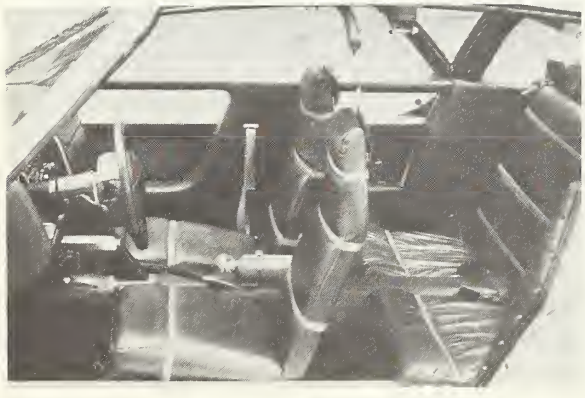
An electronic driver display, integrated with the microcomputer, presents standard dashboard data such as fuel level, speed, engine rpm, etc., in precise, easy-to-read, luminescent bars and/or numbers. Its flexible format feature enables the driver to select either of two display modes--normal (D) and status (E). Legends for these modes appear below and above the digital readout panel, respectively. A third mode alerts the driver of equipment malfunction and impending emergency situations.

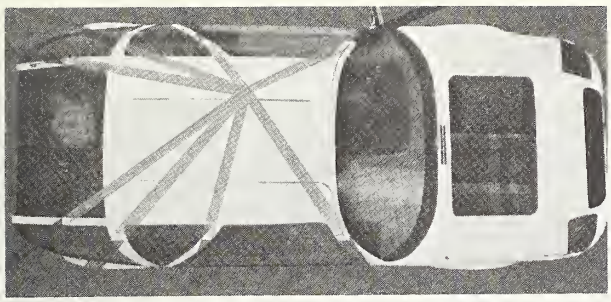


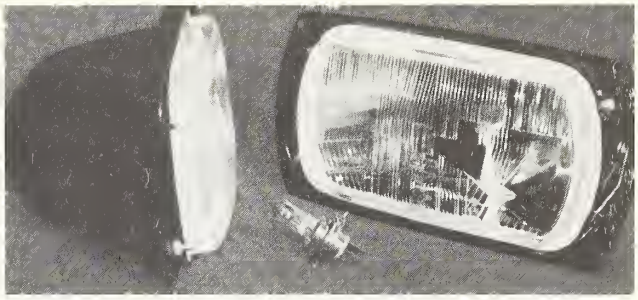
Comparison of Weight, Size, and Accommodations

Vehicle	Weight Lbs.	Fuel Economy (Combined) Miles/Gallon	Length In.	Width In.	Height In.	Wheel-Base In.	Luggage Volume Ft^3	Front Width/Headroom/ Legroom In.	Rear Width/Headroom/ Kneeroom In.	Total Interior Volume Ft^3
RSV	2190	34	170	70	55	104	13	52.0/38.5/44.5	50.0/38.0/29.0	98
Maverick (4-door)	3166	24	194	71	53	110	11	54.3/37.5/40.6	52.2/36.0/32.0	87
Pinto	2562	30	169	69	51	95	6.3	52.5/37.3/40.8	50.5/35.7/30.3	77
Honda Accord	2045	42	163	64	52	94	14	2x20.5/36.5/41.3*	51.5/34.0/24.5*	82

*Estimate

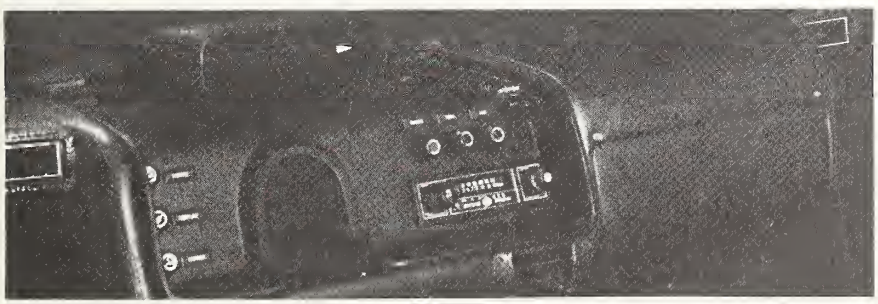


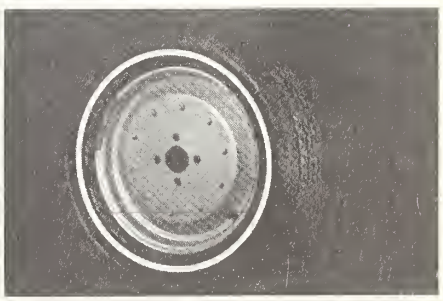


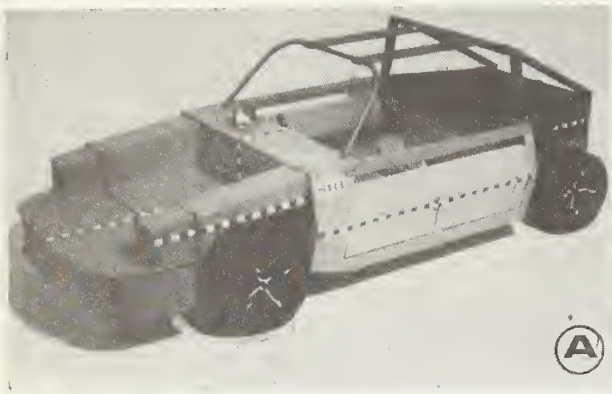


3.5 Accommodations

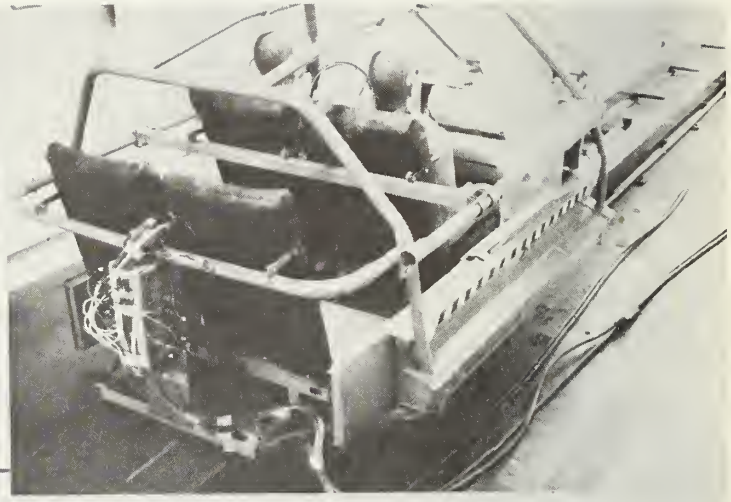
- Gullwing doors provide easy entrance to and exit from front and rear compartments and need only 17 in. of clearance between cars in parking spaces.
- Front and rear comfort contour seats accommodate occupants ranging in size from the 5th percentile female through the 95th percentile male, and work in conjunction with restraint systems to minimize injury.
- Approximately 13 cubic feet of luggage compartment space holds normal vacation luggage for a family of four.
- Outstanding all-around vision is provided--325° of totally unobstructed driver visibility.
- Rectangular headlights feature better light distribution in well-controlled beams with less weight.
- A uniquely designed dashboard is comprised of conveniently accessible operating controls, luminescent flexible-format digital readout, a Citizens' Band radio/AM-FM stereo cassette combination, and heater/air conditioner controls.
- Lightweight wheels improve handling performance, and Advance Concept Tires (ACT) can run flat, eliminating bulky spares and roadside tire changes.



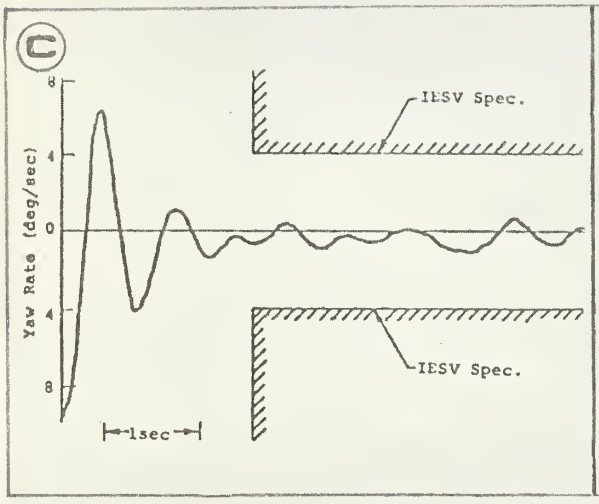


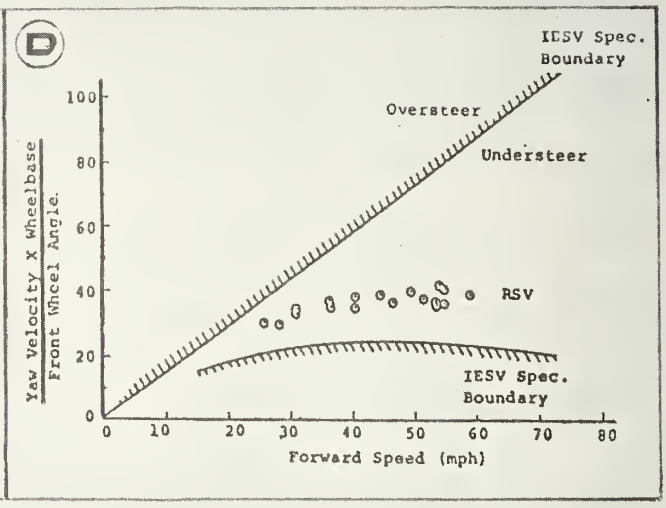


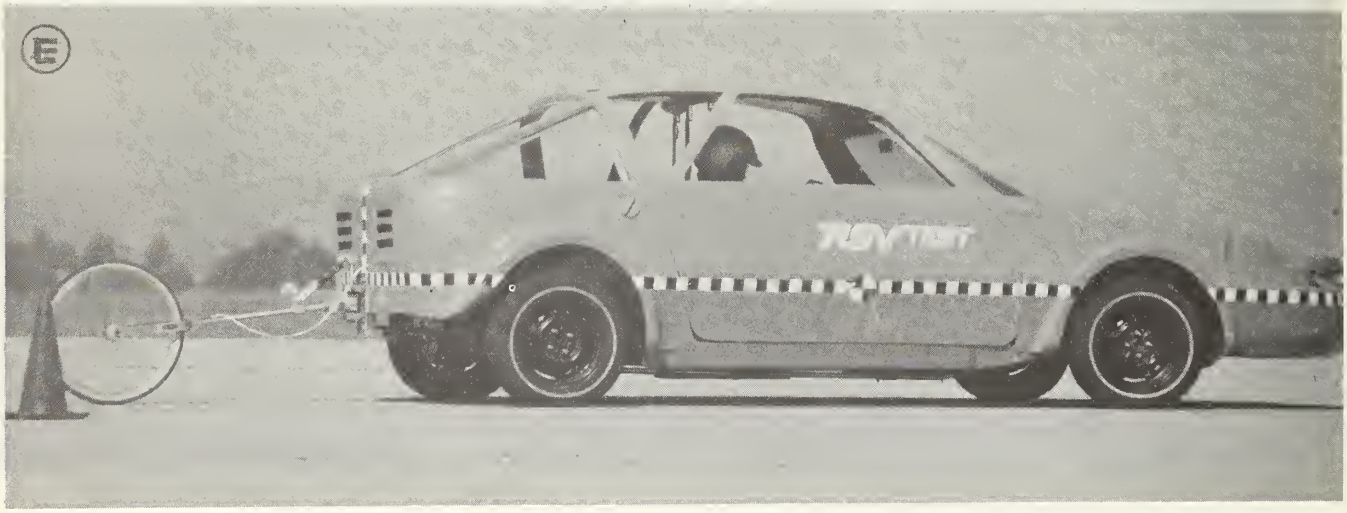
A



B


C
IESV Spec.
IESV Spec.
Yaw Rate (deg/sec)
8
4
0
4
8
1sec


D
IESV Spec.
Boundary
Oversteer
Understeer
RSV
IESV Spec.
Boundary
Yaw Velocity X Wheelbase
Front Wheel Angle.
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
Forward Speed (mph)


E

4.0 PERFORMANCE

4.1 Subsystem Tests

Extensive safety performance testing has been conducted to optimize and ensure RSV compliance with design specifications. Scale models of the RSV (A) were constructed and tested at Stanford Research Institute to obtain preliminary performance characteristics of the RSV structure.

Restraint (airbag) sled tests (B) performed at the Minicars VEAC II facility enabled occupant restraint systems for various anthropomorphic size ranges and seating positions to be experimentally refined.

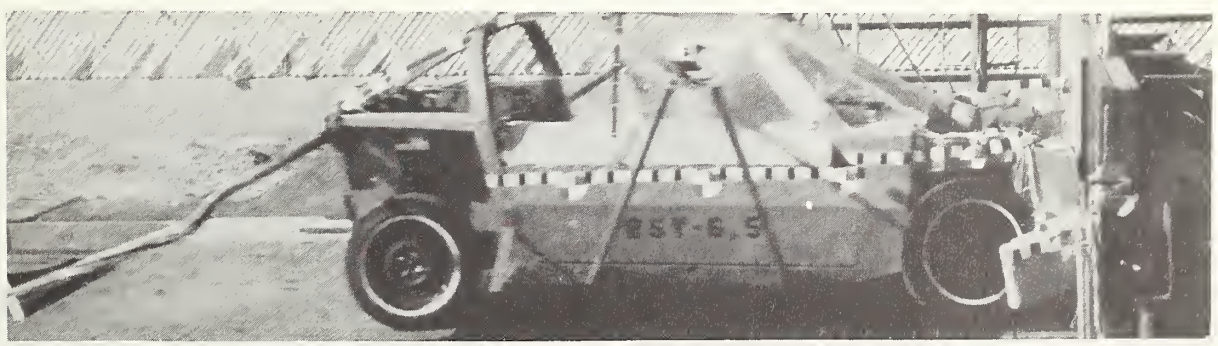
4.2 Handling and Braking

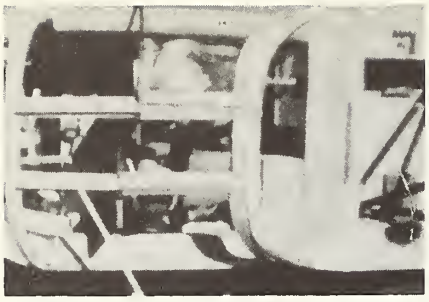
Four-wheel independent suspension and hydraulically assisted anti-skid disc brakes provide a 30% shorter stopping distance than is provided by most other cars produced in the U.S.

The yaw response (C) and (D) results shown on the adjoining page and other tests conducted by Systems Technology, Inc. on the operational RSV (E) indicate that it meets almost all major handling requirements and design goals previously specified.

4.3 Impact Testing

To ensure minimal occupant injury over the full range of practical speeds and collision modes, Minicars, Inc. has conducted full-scale barrier and vehicle-to-vehicle crash tests using instrumented anthropomorphic dummies, restraints, and padding in appropriate structural configurations. The barrier tests involved frontal and frontal offset impacts ranging from 40-52 mph.





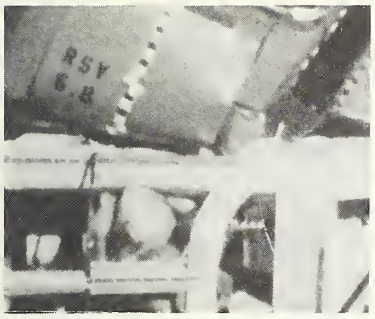
Vehicle-to-vehicle tests included 80-mph frontal offset collisions and front-to-side perpendicular and angular impact (see above sequence) and aggressivity tests at closing velocities to 58 mph. To represent the range of vehicles of different weights, geometries, and constructions in the traffic mix, Chevettes, Pintos, Volvos, and Chevrolet Impalas were tested against the RSV.

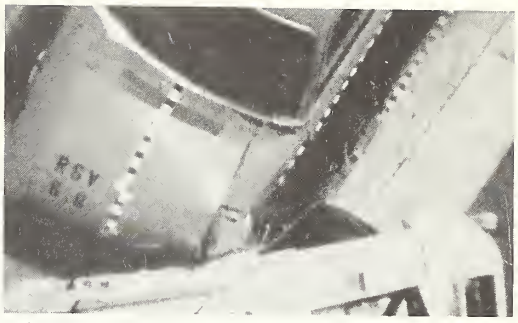
These tests indicate that the RSV structure and driver and passenger restraint systems can more than satisfy the Government criteria for occupant survival with minimum injury at speeds representing about 75% of the societal costs of impacts in each accident mode.

4.4 Damageability and Pedestrian Safety

Low speed damageability and pedestrian impact tests have also been successfully conducted. The damageability tests indicate no damage at 10 mph and no damage past the replaceable nose module at 20 mph.

Pedestrian impact tests (sequence below) to 25 mph produced very low dummy injury measures in contact with the hood and relatively low-velocity contact with the ground.





4.5 Emissions and Fuel Economy

Minicars has been assured by the Honda Motor Company, suppliers of the powertrain, that the Accord CVCC four-cylinder stratified charge engine can satisfy all applicable emissions regulations to 1984 and provide good performance with high fuel economy. The current version of the engine will produce 0.28 gram/mile of hydrocarbon emissions, 2.4 grams/mile of carbon monoxide, 1.17 grams/mile of nitric oxide, with a fuel economy of 31 mpg urban, 39 mpg highway, for a combined driving economy of 34 mpg. Acceleration performance will be 0-60 mph in 16 seconds.

Preliminary tests with the smaller Civic engine modified for installation in the RSV operational test vehicle indicated that the performance is sensitive to the specific details of the modifications, which must be engineered and refined.

4.6 Weights and Costs

Weight and manufacturing cost analyses based on producible subsystems for a Base RSV were prepared by the responsible subcontractor and/or by Minicars. These analyses were combined and are presented on the following page. Subsystems of questionable benefit/cost (still in research) were excluded and listed separately with attendant weights and costs and with the optional radio and air conditioner. Consumer prices for either the Base or the Research RSV would be approximately 34% more than those shown.

RSV COST AND WEIGHT SUMMARY

RSV System (RSV-S----)		Weight (lb)	Mfg. Cost ($)
0000	Total Finished Body (Includes Doors)	679.3	653.18
100	Cooling System	22.6	26.24
200	Fuel Tank, Filler and Emissions	26.7	19.74
300	Propulsion, Rear Suspension and Accessories	608.9	736.40
400	Front Suspension and Steering	102.5	93.76
500	Brake Lines	5.8	12.04
600	Gear Shift	3.0	6.40
700	Brake System and Pedal Assembly	17.2	9.74
800	Parking Brake	6.0	3.97
900	Body Wiring and Electrical	42.6	32.15
1000	Heater/Ventilation	19.5	33.20
1100	Passenger Restraint	25.0	55.10
1200	Dash	8.0	10.55
1300	Wheel, Airbag Restraint Column and Sensor	43.2	97.27
1400	Latches, Locks, and Controls	5.9	8.35
1500	Floor Covering	12.1	10.54
1600	Rear Padding and Trim	7.3	5.22
1700	Roof Liner Pillar Pads and Trim	17.6	16.75
1800	Rear Passenger Restraints	16.0	34.60
1900	Rear Seat	12.0	27.50
2000	Center Spine Cover	10.0	6.50
2100	Driver Seat	29.0	30.79
2200	Passenger Seat	29.0	30.79
2300	Body Weather Sealing	6.0	5.35
2400	Body Glazing	28.9	32.57
2500	Engine Cover	4.0	6.30
2600	Windshield Wiper/Washer	8.0	13.92
2700	Front and Rear Bumper	18.0	21.24
2800	Front Bulkhead	5.0	6.50
2900	Front and Rear Lighting	11.4	17.87
3000	Front and Rear Body Glove	56.0	149.00
3100	Hood	11.1	14.55
3200	Wheels and Tires	166.4	59.00
3300	Indirect Vision	1.4	1.41
3400	Instrument Panel	4.2	9.01
3500	Doors (Padding, Glazing and Trim)	42.4	19.70
3600	Hatchback	24.6	10.49
3700	RSV Accessories	8.1	6.75
3800	Miscellaneous Adjustments, Assembly, etc.	74.1	-7.00
TOTAL	BASE MODEL RSV	2218.8	$2327.44
	Substitute Fuel Cell	-15.6	122.76
	Substitute Anti-Skid Brake System	19.4	168.39
	Substitute Radar, Microcomputer and Display	11.4	191.00
	Substitute ACT Tires and Aluminum Wheels	-23.5	107.40
	Substitute Mylar Laminated Glazing	-19.3	120.67
	Option CB/AM-FM Cassette Radio	5.5	144.00
	Option Air Conditioning System	48.8	285.00
TOTAL	RESEARCH MODEL RSV	2245.5	$3466.66

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